Mesh-Free Kinetic Simulations of the Plasma-Wall Transition Region

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Abstract

Processes in the edge layer of modern fusion devices often occur on widely disparate length- and time-scales. Contemporary simulation tools often deploy ad hoc assumptions and approximations for microscopic phenomena for which self-consistent ab initio models in principle exist, but are still computationally too expensive or complex to implement. Recently mesh-free methods have matured into a new class of tools for such first-principles computation, which thanks to their geometric flexibility are highly promising for tackling complicated tokamak regions. One major drawback of mesh-free methods such as tree-codes [1] or the fast-multipole-method is the lack of general means of representing solid structures and their associated boundary conditions, which is imperative for important edge regions such as the divertor. One way of treating these special features is to discretise the corresponding differential equation on the boundary using an additional finite element procedure, called 'Boundary Element Method' [3]. Another is to solve the problem analytically in advance and specify the complete potential core for the problem [4]. The first doctrin is complicated in its implementation and congruously did not make it beyond an experimental phase to the date. The latter is clearly not felxible enough to adopt the mehtod for a wider range of problems and must therefor be seen as a proof of principle.

In this work we report on recent studies with the parallel tree-code PEPC-B [2] for fusion edge plasma simulations, focussing in particular on its adaptation for fully kinetic simulations of the plasma-wall transition region (sheath). For this purpose we developt a new easy concept to represent solid structures in mesh-free methods. In order to remain within the inherent nature of the code-class we build walls of stationary 'wall-particles'. These wall-particles can charge during simulations runs giving a natural way to represent the surface charges of a floating wall. In first attempts to validate this new concept we set up a quasi 1D scenario for a plasma sheath transition region. First results are compared with older but equivalent PIC resultsas well as with semi-analytical works. Showing good agreement especially in the values for the potential drop we move on to detailed analysis of the kinetics in the sheath-region.

References

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